Cincinnati, Ohio to examine the transmission of digital signals in the analog broadcasting bands. Significant system simulations and modeling have been completed, and USADR is implementing new prototype hardware. Preliminary laboratory and field tests have begun. More comprehensive testing is scheduled to commence in the first quarter of 1999. Based on the advanced stage of USADR's development work and the expectation that commercial transmission systems will be available within 18 months, USADR has initiated this rulemaking to encourage the Commission to develop the rules necessary to quickly implement IBOC DAB.

III. THE COMMISSION SHOULD INITIATE A PROCEEDING TO ESTABLISH RULES FOR IBOC DAB.

A. Digital Radio Broadcasting is in the Public Interest

1. Digital technology possesses significant advantages over current analog broadcasting

The speed at which the public has upgraded to digital technology across a wide array of media reflects the recognition that digital technology possesses significant advantages over analog. The Commission has consistently supported upgrading analog systems to digital as technology has made that possible.[16] The Commission's rationale for supporting this transition was stated early in the digital television proceedings:

> The NTSC system has been serving the American public for almost 50 years. While the NTSC transmission standard has proven to be remarkably durable and adaptable to changes over the years, it reflects the technological limits of the early days of

[16] *See Notice of Proposed Rulemaking and Further Notice of Inquiry* in Gen. Docket No. 90-357, 7 FCC Rcd 7776, 7780 (1992) (stating "[w]e believe that existing radio broadcasters can and should have an opportunity to take advantage of new digital radio technologies, and we are optimistic that technical advances will, in the near future, permit both FM and AM broadcasters to offer improved digital sound").

> television development, and is perceived today as limited in video quality and audio fidelity. More importantly, it no longer represents the limits of the present and anticipated future technological possibilities in the home video delivery service. Even with the various changes and improvements in the hardware over the years, the NTSC standard still suffers from a number of defects that are inherent in its design or are byproducts of adding color information to the black-and-white transmission without increasing the transmission bandwidth.[17]

The Commission recognized television technology had reached the limits of its ability to improve and to adapt in parallel to evolving consumer expectations. Digital transmissions held out the promise of delivering programs with significantly improved video and audio quality.

Currently, radio broadcasting in the United States is also being provided using technology whose intrinsic limitations do not permit further material improvement. The history of analog radio broadcasting in many ways mirrors that of analog television. Like analog television, analog radio has been the established technology for a considerable period of time. Since its invention in the 1920s, radio broadcasting has passed many milestones. During the most recent thirty year period, however, technological change in analog radio has been confined to minor improvements in the basic analog technology. Thus, while it has been adapted over the years, it has reached a plateau of development, above which no material improvements are possible.

2. DAB possesses many superior intrinsic features

As noted above, DAB is capable of providing vastly improved service to the public. Its principal merits include enhanced sound fidelity, improved robustness, new radio features and the ability to provide enhanced auxiliary services. Digital radio can increase radio sound quality

[17] *Notice of Inquiry* in MM Docket No. 87-268, 2 FCC Rcd 5125, 5126 (1987).

so that it more closely matches the original source material, particularly digitally recorded music. FM DAB provides the listener a sound quality that is virtually the same as a CD, which has become the standard dictated by the marketplace AM DAB can provide sound quality comparable to today's FM.

This improved audio fidelity can be achieved in combination with improved "robustness" of the radio signal. Robustness refers to the ability of the signal to withstand interference from other radio broadcasts, multipath fading and noise. Improved robustness results in fewer holes within a station's coverage area. Multipath fading refers to the fluctuation in received signal quality caused by reception of multiple reflections of the transmitted signal off of man-made and natural structures. Interference refers to the reception of undesired signals which degrade reception of the desired signal. Interference and multipath fading together limit the robustness in the FM band. AM signals receive significant degradation from structures, as well as interference from atmospheric conditions and man-made and natural sources of noise. The digital processing of both the digital and analog signals in the USADR system will help overcome these problems and increase robustness even in the interim hybrid mode when analog and digital signals are broadcast simultaneously.

IBOC DAB will facilitate the introduction of new auxiliary services in addition to the improved quality and performance noted above. The USADR system includes auxiliary services which are significantly more robust and higher quality than today's subcarrier services. Although market forces will determine the best auxiliary services to provide, USADR anticipates a growing demand for transmission of information as well as other point-to-multipoint digital services.

3. The Commission has determined that the introduction of digital radio is in the public interest

The Commission has long recognized the need to incorporate digital technology in radio broadcasting. In its first *Notice of Inquiry* regarding digital radio, the Commission noted that digital modulation is increasingly common in radio telecommunications, including, for example, cellular telephones.[18] It also recognized that digital audio media are developing rapidly, that the increased sound quality they offer is gaining acceptance by consumers, and that it is technically feasible.[19] The Commission concluded:

> We continue to support efforts to implement terrestrial in-band DARS technology. We believe that existing radio broadcasters can and should have an opportunity to take advantage of new digital radio technologies, and we are optimistic that technical advances will, in the near future, permit both FM and AM broadcasters to offer improved digital sound. To this end, we are committed to continuing our work with the broadcast industry to ensure that broadcasters are able to promptly implement terrestrial DARS.[20]

More recently, in the satellite DARS proceedings, the Commission reaffirmed its commitment to terrestrial digital radio, stating:

> We believe that existing radio broadcasters can and should have the opportunity to profit from new digital radio technologies. And we anticipate that technical advances will soon permit both AM

[18] *Notice of Proposed Rulemaking and Further Notice of Inquiry* in Gen. Docket No. 90-357, 7 FCC Rcd 7776, 7778 (1992).

[19] *Id.*

[20] *Id.* at 7780.

> and FM broadcasters to offer improved digital sound. . . . Some of the systems being tested are designed specifically to permit digital broadcasting within the existing AM and FM bands. We fully support these developments, and we see great promise in these innovations for providing improved services to consumers. These innovations will also help promote the future viability of our terrestrial broadcasting system, which provides local news and public affairs programming. When the test results indicate the feasibility of implementing such systems, we will act expeditiously to consider any appropriate changes to our rules.[21]

This Petition provides the Commission with the evidence that the time is now ripe to consider such changes.[22]

In sum, the case for incorporating digital technology into radio broadcasting is undisputed. As with digital television, the public interest would be served by the ability to deliver CD-quality sound and simultaneously correct some of the defects inherent in analog radio.

B. <u>IBOC Technology is the Best Means of Implementing Digital Radio</u>

Just as the decisions made in the 1920's and onward enabled the growth and success of the present radio broadcasting market, so the choices the Commission makes as digital

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21 *Report and Order* in Gen. Docket No. 90-357, 10 FCC Rcd 2310, 2314 (1995).

22 The International Telecommunications Union ("ITU") has also recognized the compelling advantages of digital radio and has done significant work to develop standards for digital radio. In its 1995 Special Publication on the system and service requirements of digital radio, the ITU set forth several compelling reasons for the introduction of terrestrial and satellite digital broadcasting. For example, it stressed that the digitalization of broadcasting systems is important to ensure the greatest possible commonality of the technical standards used in the different media, such as cable distribution and computer technology.[22] The ITU also recognized the many intrinsic advantages of digital broadcasting over analog, such as the ability to overcome multipath problems, greatly improved audio quality, and high spectrum efficiency. International Telecommunications Union, Radiocommunications Bureau, *Terrestrial and Satellite Digital Sound Broadcasting to Vehicular, Portable and Fixed Receivers in the VHF/UHF Bands* 50 (Geneva 1995).

technology is introduced will define the parameters of radio service in the 21st century. The transition from today's analog radio transmission system to terrestrial DAB has to be undertaken with much thought and care. It is of critical importance that the transition to a new audio delivery system provides the listening public with increased fidelity and sound quality as well as new and innovative digital transmission services. Also, it is vital that the migration from today's mature AM and FM transmission systems to a digital transmission system does not undermine the viability and stability of the existing AM and FM radio industry.

A new allocation of frequencies for terrestrial DAB is clearly not the answer. In many countries it is exceedingly difficult, if not impossible, to obtain access to any frequency band that has favorable propagation characteristics (*e.g.*, UHF or VHF) for use by DAB, and there is no frequency available for this purpose in the United States. Sharing with existing users in the VHF or UHF bands in the United States would be impossible in light of the existing uses of these bands.[23] The move to higher bands would dramatically increase the costs of the transmission system but might not necessarily improve sound quality. Furthermore, the introduction of terrestrial DAB in a new frequency band could create tremendous turmoil in the radio industry, disrupting service to the public, and impose a significant administrative burden on regulatory authorities.

As discussed more specifically below, there are several reasons why IBOC DAB should be the means of implementing terrestrial DAB in the United States. IBOC DAB is the only

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[23] The VHF and UHF bands are currently used for commercial television, important government communications and new emerging wireless services. *See* 47 CFR § 2.106.

proposed technology that integrates digital broadcasting into the existing analog AM and FM radio transmission system, obviating the need to allocate new spectrum. Furthermore, the integration of IBOC DAB can be accomplished with a minimal economic disruption and with no required change in listener behavior; simultaneously, it provides the consumer with improved sound quality and enhanced auxiliary services. Finally, as demonstrated in this Petition, IBOC DAB is technically viable.

1. IBOC is frequency efficient

In recent years, there has been increasing demand for spectrum to support new and innovative services such as PCS, land mobile services, digital television, and mobile satellite services for data and voice. As regulatory authorities have analyzed each of these technologies, they have repeatedly stressed the need for spectrum efficiency.[24] It is well recognized that given the current congested use of the spectrum, it would be extremely difficult to accommodate new services. Therefore, regulatory agencies have indicated that they would look favorably on any proposal or technology that is spectrum efficient.[25] This important policy goal also should be applied to terrestrial DAB. Thus, a DAB system that does not require a new frequency allocation should be favored over any system that does. This is particularly important for radio, because it would be preferable to operate a terrestrial DAB system within the existing medium frequency

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[24] *See, e.g., Fifth Report and Order* in MM Docket No. 87-268, 12 FCC Rcd 12809, 12812 (1997) (stating that one of essential objectives of DTV proceeding was promotion of "spectrum efficiency").

[25] *See Report and Order* in Gen. Docket No. 90-217, 6 FCC Rcd 3488 (1991); recon. granted in part, *Memorandum Opinion and Order*, 7 FCC Rcd 1808 (1992); *Tentative Decision* in ET Docket No. 91-280, 7 FCC Rcd 1625 (1992); *Tentative Decision and Memorandum Opinion and Order* in Gen. Docket No. 90-314, 7 FCC Rcd 7794 (1992).

and VHF bands, which offer more favorable propagation characteristics. IBOC DAB meets the spectrum efficiency goal since it does not require a new allocation of frequency.

2. <u>IBOC ensures a seamless transition from analog to digital</u>

IBOC DAB will provide the flexibility required for a seamless transition from analog to digital. The U.S. radio industry is highly diverse, characterized by the existence of more than 12,000 radio stations. This diversity is a reflection of the varied needs of the listening public. The ability to foster a flexible introduction of digital radio is necessary in this setting in order to minimize disruptions in service.

IBOC technology allows consumers to continue to use analog receivers for an extended period of time. Therefore, it minimizes disruptions and dislocations. USADR's system has been engineered to permit listeners and broadcasters to upgrade to digital at their own pace. Upgrade decisions can be based on the economic needs of local stations and local listener demand without the threat of abrupt disruptions in local service. Consumers will be able to adapt at their own pace and as appropriate to their specific use of radio. They will not face an immediate, across-the-board shift to digital technology. Similarly, the transition from hybrid to all-digital will be at the discretion of the broadcaster and driven by market forces.

IBOC's ability to provide a seamless transition from analog to the interim hybrid period, to the all-digital period, provides the additional public service of protecting the Emergency Alert System. As is discussed in Section IV(E) below, by retaining the analog function during the hybrid mode, IBOC will ensure that segments of the population are not suddenly cut off from public safety announcements and disaster relief information.

3. IBOC benefits radio listeners

IBOC DAB will provide listeners enhanced audio quality and additional services. It will also allow listeners to maintain their patterns of radio use; listeners will continue to find stations at their existing dial position. Moreover, the receiver will possess the same outward features and functions as analog radio.

IBOC DAB receivers will be affordable to the average consumer. If the promise of terrestrial DAB is going to be realized, the cost of the DAB receiver, when produced in large volume, must be low enough to be affordable to the average consumer. Before broadcasters are going to commit to upgrade to terrestrial DAB. they need assurances that listeners will have reasonable access to DAB receivers. USADR's IBOC terrestrial DAB system was designed to provide a cost-effective means for listeners to upgrade to digital.

4. IBOC benefits broadcasters

IBOC preserves broadcasters' investments in AM and FM stations during the transition from analog to digital. At the same time, IBOC ensures equal opportunity for both AM and FM broadcasters to access new digital technology. If FM broadcasters were provided the opportunity to upgrade to digital, but AM broadcasters were denied a corresponding opportunity to upgrade, it would create a further economic dislocation between AM and FM broadcasters. The USADR IBOC system eliminates this problem by providing both AM and FM radio broadcasters the opportunity to upgrade performance and sound quality

Another benefit of IBOC is that it will not require the development of a new broadcast infrastructure. For broadcasters, their studios, towers, antennas and much of their equipment will remain unchanged. Each station will require a new exciter, but some stations will be able to upgrade to IBOC DAB without replacing transmitters. While such costs are not trivial, all such upgrades could occur through the normal life and maintenance cycle of radio broadcasting equipment. Thus, the timing and the capital investment required to implement IBOC DAB avoids any comprehensive and financially disastrous obsolescence of radio broadcasting assets. The flexibility inherent in IBOC provides additional opportunities and protection for broadcasters. Digital radio can be phased-in based on market demand or as part of the broadcaster's normal equipment replacement cycle. There will be many broadcasters that choose to upgrade as soon as possible, but IBOC will provide additional time for many who, for financial or other reasons, chose not to upgrade quickly.

5. <u>IBOC will facilitate the introduction of enhanced auxiliary services</u>

The digital bit stream used for audio broadcasting in the IBOC system also supports auxiliary services. USADR has engineered its system to permit upgrades of existing subcarrier services using datacasting capabilities, which provide for both program associated data as well as new or upgraded ancillary data services. By upgrading existing subcarrier-based services and offering a means for introducing new services, IBOC DAB will serve the public interest.

6. <u>IBOC minimizes regulatory burdens on the Commission</u>.

IBOC DAB will be administratively efficient to implement. Unlike the introduction of other digital technologies, the introduction of IBOC DAB will impose minimal administrative burdens. There is no requirement to allocate new spectrum for DAB or to license service providers. Once a DAB system is adopted as a standard, the Commission's responsibilities will be limited to the need to implement interference criteria for the new digital broadcasts and adopt a transition plan, which protects analog broadcasting for a reasonable period but also promotes a transition to the all-digital period.

7. <u>USADR has demonstrated the technical viability of its IBOC DAB technology</u>

In this Petition, USADR provides substantial amounts of information demonstrating the viability and performance of its IBOC system. Additionally, USADR provides independent verification of its internal analysis. A report prepared by R.L. Pickholtz, Ph.D. and B.R. Vojcic, D.Sc. concludes that "IBOC FM/DAB will result in CD-like quality" and that the interference from the host DAB to the host FM and first adjacent channel FM is minimal in most operational scenarios."[26] The Pickholtz and Vojcic report further confirms "the feasibility of the [AM] engineering design." USADR has provided in this Petition a detailed summary of its AM and FM system design as well as extensive simulations demonstrating the performance of its system. Collectively, this information demonstrates the technical viability of IBOC DAB.

IV. EXISTING RADIO BROADCAST ENVIRONMENT

In order to effectively design and evaluate IBOC DAB technology, it is necessary to have a complete understanding of the existing AM and FM broadcast environment. Because a core component of the IBOC concept involves compatibility with existing analog broadcasting, USADR has conducted extensive studies of both the AM and FM broadcast environments to determine both the structure and quality of analog broadcasting in these bands. USADR's

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[26] *See* Appendix I.

studies have focused on the impairments and interference which frequently limit the effectiveness and coverage of existing analog broadcasting. USADR has used this information to balance the various components of its IBOC DAB system to optimize the system's performance and compatibility.

A. FM Radio

1. Regulatory treatment

Each FM station is licensed to operate in a 200 kHz channel in the 88-108 MHz band.[27] The technical rules applicable to a particular FM station are determined by whether the station is a Class A, Class B or Class C station.[28] Based on the effective radiated power and antenna height above average terrain authorized for a particular class, the Commission has established a protected contour which represents the area within which the station is protected from interference. The Commission has established a predicted distance from the transmitter to the edge of the protected contour for each class. Because terrain will vary for each station, the actual distance to the edge of the protected contour will be different from the predicted edge of coverage.[29]

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27 47 C.F.R. § 73.201. These channels are designated as Channel 201 (88.1 MHz) through Channel 300 (107.9 MHz). Channels 201-220 are reserved for use by noncommercial educational FM broadcast stations. 47 C.F.R. § 73.501(a).

28 *See* 47 C.F.R. § 73.210. For example, the allowable transmitter power and antenna height for a particular station will vary based on its class.

29 As is described in greater detail below, USADR's studies have indicated that band impairments and interference, particularly in light of short-spaced stations, frequently restrict actual station coverage.

The Commission specifies minimum distance separation requirements between FM stations. These requirements vary in relation to the class of the relevant stations, and whether the stations are operating on the same channel ("co-channel") or on adjacent channels.[30] For example, a Class A station must be 226 kilometers from a Class C co-channel, but only 165 kilometers from a Class C first adjacent and 95 kilometers from a second or third adjacent.[31]

The Commission also licenses low power translator and booster stations in the FM band in order to supplement the coverage of a primary FM station.[32] These stations extend broadcasting to areas in which direct reception of radio service is inadequate because of distance or physical barriers, such as mountain ranges. Translator stations, which rebroadcast the primary FM signal on a different frequency, are not licensed to originate programming, except in very limited instances. Booster stations, which operate on the same frequency as the primary station and are owned by the primary station licensee, are not permitted to originate programming under any circumstances. As of August 31,1998, there were 3,081 FM translator and booster stations licensed by the FCC.[33]

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[30] *See* 47 C.F.R. § 73.207. Stations operating 200 kHz away from a host station are designated "first adjacent," stations operating 400 kHz away are designated "second adjacent," and those 600 kHz away are designated "third adjacent."

[31] *See* 47 CFR § 73.207, Table A.

[32] *See* 47 C.F.R. § 74.1201 *et seq.*

[33] FCC News Release, "Broadcast Station Totals as of August 31, 1998" (released September 11, 1998).

Lower cost receivers, such as personal radios and other portables, are much more susceptible to adjacent channel interference.

To more fully understand the effects of adjacent channel interference, USADR retained the firm of Moffett, Larson and Johnson ("MLJ") to characterize the existing FM interference environment.[39] The MLJ Report found existing analog interference is more severe than would be predicted based on the current FCC rules and often seriously impacts the coverage of existing analog stations. Because many existing FM stations were licensed under less stringent interference protection criteria than currently exist, many areas of the country have severe short-spacing problems among stations. Figure 1 below depicts those areas of the country where existing analog stations are subject to interference from co- and adjacent channels, as defined under the Commission's rules.[40]

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[39] A summary of the results of that study is presented in Appendix D.

[40] *See* Appendix G.

AREAS OF POSSIBLE INTERFERENCE TO COMMERCIAL FM STATIONS

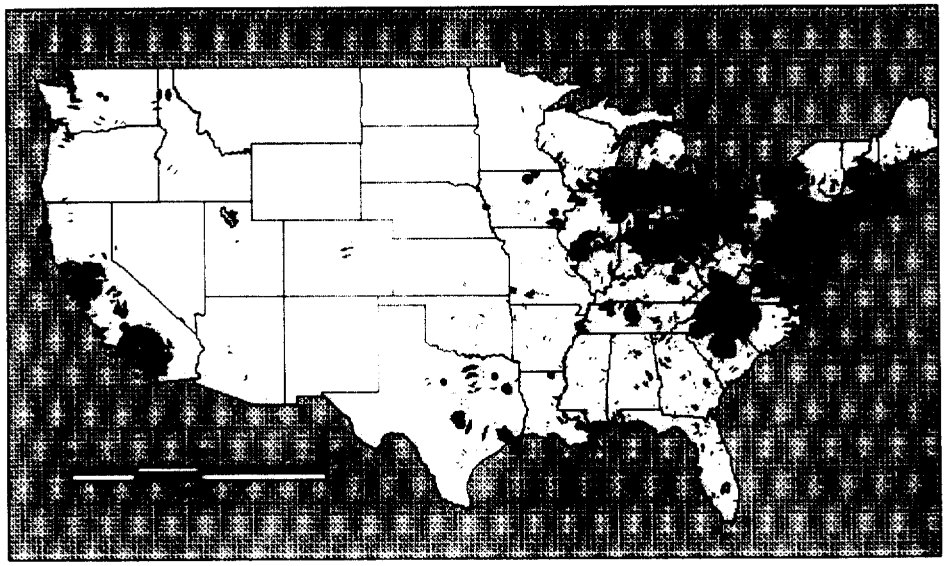

Figure 1 - Areas of Possible Interference to FM Stations

USADR conducted this analysis in order to design its FM IBOC DAB system to perform in the existing interference environment.

4. Subcarriers

The FCC has authorized both AM and FM stations to use subcarriers to offer subsidiary communication services ancillary to the primary analog audio signal.[41] These subcarriers are used to provide various audio and data services such as foreign language programming, paging, stock market reports and traffic control signal switching. Users typically have special receivers to use these subcarrier-based services. Although subcarrier services are not a large component of

[41] *See* 47 C.F.R. § 73.127(a) [AM]; 47 C.F.R. § 73.295(c) [FM].

the broadcast industry, the subcarrier community will have an interest in what impact DAB will have on these services.

Broadcast station licensees are authorized, without prior FCC approval, to transmit subcarrier broadcast services in accordance with specified technical standards.[42] Existing subcarriers can either be analog or digital, with the digital subcarriers being the more robust. Although many frequencies are used for subcarrier operations, the most common frequencies are 57 kHz, 67 kHz and 92 kHz. Approximately 44% of the stations use at least one subcarrier and 7.8% lease two subcarriers.[43] The total revenue for the subcarrier business is approximately $40M.[44] USADR has designed its system to minimize impacts to existing subcarrier services.

B. AM Radio

1. Regulatory treatment

The AM band is divided into 10 kHz channels within the 540-1700 kHz band. AM stations are licensed to broadcast across a 20 kHz bandwidth, resulting in interleaved adjacent channels. They operate within certain power usage, time and coverage parameters set through

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[42] 47 CFR §§ 73.293, 73.319 and 73.322. To the extent subcarriers are used to provide common carrier services, appropriate FCC authorization is required. For private carriage, a certification that the subcarrier will only be used for permissible purposes must be filed with the Wireless Telecommunications Bureau. Use of the subcarrier for land mobile services requires the prior submission of a certification that the subcarrier will be used only for permissible purposes by eligible users and that any interconnection with a telephone exchange will be made in accordance with Section 331 of the Communications Act. *See* 47 C.F.R. Part 20.

[43] National Association of Broadcasters, "1996 FM Subcarrier Market Report & Technology Guide" ("1996 Subcarrier Report").

[44] National Association of Broadcasters, "1994 FM Subcarrier Market Report."

specific station classifications and channel assignments.[45] AM broadcast stations are authorized to operate on either clear, regional or local channels, which define the coverage area of a given station. AM stations are, in turn, classified as either Class A, B, C, or D. These classifications are defined by power and operating time parameters.

There are three types of service areas for AM broadcast stations: primary (where groundwave is not subject to objectionable interference or fading); secondary (served by skywave and not subject to objectionable interferences but where the signal is subject to intermittent variations in strength) and intermittent (service by groundwave beyond primary service area and subject to some interference and fading). Class A stations are able to serve all three areas. Class B stations serve all three, but may be limited in secondary and intermittent areas due to interference from other stations. Class C and D stations are effectively limited to primary areas.

2. Impairments[46]

Even in the absence of interfering stations, current analog AM broadcasts are subject to a number of degradations which are present in a received signal. These "impairments" have a direct impact on audio quality. Impairments are due to perturbations in the propagation channel caused by grounded conductive structures or noise from sources other than interfering stations. The characteristics of these impairments have been studied and measured by USADR, and the results are being used directly in USADR's system design to optimize performance.

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45 *See* 47 C.F.R. § 73.25.

46 The effects of AM band impairments are discussed in greater detail in Appendix H.

a. Grounded conductive structures

Grounded conductive structures can cause the magnitude and phase of an AM waveform to change. Bridges, power lines, overpasses and overhead signs typically found along highways are examples of grounded conductive structures. Degradation of the received signal occurs in part because the wavelength of the AM band is large compared to the dimensions of these structures.

USADR has characterized wave propagation in the AM band in the presence of grounded conductive structures. Specifically, it has determined the magnitude and phase changes caused by grounded conductive structures by conducting extensive field work on three stations.[47] Results show that approximately 5% of all overhead wires, 50% of all overhead signs, and almost all overpasses result in noticeable changes in the magnitude and phase of the received AM signal. Signal degradation resulting from overhead wires are slightly more severe at higher frequencies. For example, a typical fade at 740 kHz is approximately 3 dB, at 1150 kHz it is approximately 6 dB, and at 1660 kHz it is approximately 9 dB.

It is commonly understood that fading (which USADR has determined is primarily from grounded conductive structures) significantly affects listener perception of AM radio. The percentage of time that grounded conductive structures affect signal propagation can be high in some instances, such as urban locations and highways near urban areas, where overpasses and signs are common. As a result, there is a strong need for an IBOC DAB system to minimize the

[47] *See* Appendix H for more details regarding this field work.

effects of grounded conductive structures in order to improve overall quality and robustness of the digital signal.[48]

b. Noise

Noise has a significant impact on existing AM analog coverage, and therefore, is a key factor to be considered in the design of an AM IBOC DAB system.[49] Typical noise temperatures in the AM band range from 1 million degrees K to 100 million degrees K, which is two to four orders of magnitude greater than present in the FM band. Noise originates from a variety of sources, which can be grouped into man-made and natural noise.

The level of man-made noise is highly dependent on the surrounding environment. USADR has identified four environmental categories of man-made noise: business, residential, rural, and quiet rural. Sources of man-made noise impacting the AM signal include power lines and power generation equipment, automobile ignition systems, fluorescent lights, and electrical equipment such as arc welders. Although localized exceptions exist, for frequencies below 20 MHz, the dominant source of noise is from power lines. Power line noise is generated by three types of phenomenon: (1) gap-discharge, which is gas discharge and insulating film breakdown between high-potential points on powerlines supporting elements, (2) corona discharge, and (3) re-radiation from electrical loads. In the AM band, gap discharges generally exceed all other unintentional sources.

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48 The impairment of the grounded conductive structure is compounded by the reacquisition time required for the digital signal. Appendix F details the innovative solutions USADR has applied to this problem.

49 *See* above for a discussion of the impact of noise on the FM band.

Sources of natural noise include atmospheric (lightning), galactic, and solar. In the AM band, atmospheric noise is almost always the predominant natural noise source in temperate latitudes. USADR has taken into account these high level diverse sources of noise in the AM band in the design of the IBOC DAB system.

3. Interference environment

USADR has extensively studied interference in the AM band to assure an optimized AM IBOC system. The Commission defines the AM band as an interference-limited medium where signals from distant stations often limit potential coverage.[50] During daytime hours, interfering signals arrive via groundwave propagation. At night, additional interference arrives from reflection of distant signals of the ionosphere; this is defined as "skywave interference." In order to better understand typical levels of interference, USADR retained the firms of duTreil, Lunden & Rackley, Inc. and Glen Clark & Associates to prepare a report ("DLR/Clark Report") analyzing nighttime interference levels of AM stations.[51] As is the case with the FM band, USADR's studies conclude that significantly greater interference exists in the AM band than is defined in the Commission's Rules.[52]

a. Daytime interference

Daytime signal propagation is primarily via groundwave. The strength of groundwave signals decreases with distance, and the rate of decrease is dependent on ground conductivity,

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50 *Notice of Proposed Rulemaking* in MM Docket No. 89-46, 4 FCC Rcd 2430, 2430-31 (1989).

51 *See* Appendix G.

52 *Id.*

which varies throughout the United States. Daytime protections vary by class of station, with Class A stations receiving the highest levels of co-channel protection.

b. Nighttime interference (Skywave)

Skywave creates significant interference to the existing AM band between sunset and sunrise. Received AM signals may consist of both groundwave and skywave components. Groundwave refers to the terrestrial propagation of the signal from the transmitter to the receiver. Skywave refers to long distance transmission of AM signals resulting from reflection of the signal off the ionosphere.[53] Because ionosphere reflectivity increases at night, skywave is considered primarily a nighttime phenomenon.[54]

The DLR/Clark Report[55] indicates skywave creates significantly greater levels of interference when compared to daytime reception. USADR has used the results of the study to simulate and design an AM IBOC DAB system that provides significantly better audio quality and coverage than existing analog AM modulation when skywave interference is present.

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[53] Skywave signals can consist of several components due to reflections from different layers in the ionosphere. The ionosphere is divided into three regions designated as the D, E, and F layers. The D layer is closest to the Earth at a height of approximately 50 to 90 kilometers and is present only during daylight hours. This layer absorbs frequencies in the AM band rather than reflecting them back to Earth. At night, this layer diminishes, permitting AM waves to propagate to the E and F layers. *See* M.H. Barringer and K.D. Springer, "Radio Wave Propagation," NAB Engineering Handbook, § 2.8, 297-99 (8^{th} ed. 1992); International Radio Consultative Committee, "ITU-R Handbook on the ionosphere and its effects on radiowave propagation," ITU 235-7, Int. Telecomm. Union (Geneva, 1998).

[54] Currently, many analog stations use reduced transmit power or directional antennas to reduce skywave interference to other stations. These measures are also helpful for a DAB system, but digital signaling technology can use additional techniques such as interleaving, forward error correction, and frequency diversity to provide audio quality superior to existing analog broadcasting.

[55] *See* Appendix G.

Understanding the nature of skywave interference is essential to designing an AM IBOC DAB system that can provide robust nighttime performance. The manner in which the signal propagates via reflections from different ionospheric layers, the field strength, and the statistical time varying properties of the signal are important factors to consider in the system design. This information has been used in the simulation and design of the AM component of the USADR IBOC DAB system to optimize performance in the presence of skywave interference.

C. Receivers

Radio receivers are one of the most ubiquitous products in America today, with over 70 million units sold annually. The basic technology used in receiving radio signals was developed many years ago, and has not changed dramatically in the intervening years. There have been quality improvements, such as noise reduction technology and stereo, which are enhancements to the basic system, but not major system design changes. Conceptually, a radio receiver captures a transmitted over the air signal (with its antenna), processes the signal to separate out the desired signal from the adjacent channels, converts the signal to audio, and sends audio output to speakers.

Receivers are readily available to the public; they are sold by general retail outlets, mail order, and specialty audio stores. In addition, receivers are an integral part of automobiles. Receiver sales can be categorized into several major groupings based on the market segment served:

Type of Receiver	1996 Sales
Separate receiver components/Compact systems	10 M
Auto-Mobile, factory installed	12 M
Auto-Mobile, After market installed	8 M
Home table top and clock radios	17 M
"Boom" boxes, with CDs or cassettes	15 M
Personal radios with tape players	10 M
TOTAL	72 M

The manufacturing costs, and ultimate retail price paid by consumers, varies depending on the features, functionality and quality of the receiver. As a result, the costs to the manufacturer vary greatly by receiver type. High end receiver components can cost up to $250 per unit, with factory installed automobile radios costing around $200 per unit. On the other end of the spectrum, smaller personal stereo radios can cost below $30 per unit. The ultimate cost to the consumer depends on the cost of the entire distribution chain for the product and the ultimate retailer markup.

D. <u>Transmitters</u>

Each radio station broadcasts its signal using a radio transmitter and antenna. The transmitter receives an audio signal from the station, and impresses the audio onto a RF signal for amplification by the transmitter. The transmitter boosts the signal level to the station's licensed power and delivers it to the antenna for broadcast. The more powerful the transmitter, the greater the overall population that can be reached

AM transmitters primarily consist of a power amplifier and a method of adding the audio to the carrier. FM transmitters, by comparison, are essentially high efficiency amplifiers driven by an FM exciter and stereo generator. An exciter is a device which produces waveforms necessary to the transmission of a signal.

Transmitters are readily available to radio stations from a number of manufacturers. Most manufacturers serve both the AM and FM markets, although some specialize by band. Transmitters vary in price to the station based on the rated power output and the underlying technology. Traditionally, transmitters have been manufactured using high power vacuum tube technology. In the past several decades, manufacturers have also been offering solid state transmitters. These transmitters use numerous power transistors in place of tubes. They require less maintenance than tube type transmitters and are sold as an alternative to tube technology.

The price of transmitters is based on the rated power output. The more powerful the transmitter, the higher the price to the station. For example, for one manufacturer, a 1 kW AM transmitter is priced at approximately $16,000 while a 50 kW AM transmitter is priced at $180,000. For FM, a 2 kW transmitter is priced at approximately $30,000 while a 60 kW FM unit is priced at $170,000. The final price paid by a radio station depends on the features and functionality of the transmitter and any negotiated discounts.

E. <u>Emergency Alert System</u>

The Emergency Alert System ("EAS"), formerly called the Emergency Broadcast System ("EBS"), is a critical public safety and national security system which is heavily dependent on radio broadcasting. IBOC DAB will foster the continued integrity of the EAS by enhancing the viability of AM and FM broadcasting and by ensuring that the transition to digital radio will not cause disruptions in the public's ability to use existing AM and FM radios.

The 1963 establishment of the EBS created a mechanism for the President of the United States to address the nation in the event of a national emergency.[56] The President has extended the scope of the EBS/EAS by authorizing state and local emergency officials to use the EBS/EAS for alerting the public about weather events or other emergency situations. There were a total of 22,271 activations of the EAS reported to the Commission from 1976 until August 1998, with 464 activations reported in the first seven months of 1998.[57]

The Commission already has noted the critical role radio broadcasting plays in this system. In its decision creating the EAS, the Commission rejected suggestions for the EAS to be broadcast on National Weather Service frequencies. The Commission noted, "[r]adio and television broadcast stations currently reach nearly every part of the country, often with several stations. There are radios and televisions in virtually every home and business."[58] Because radios are ubiquitous and because radio broadcasting is not a subscription service, its penetration rates are not rivaled by other services. As a result, radio plays a key role in alerting the public to emergency situations.

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[56] *See Report and Order and Further Notice of Proposed Rulemaking* in FO Docket Nos. 91-301 and 91-171, 10 FCC Rcd 1786, 1788 (1994). See also 11 C.F.R. § 11.1; EAS An Overview (visited Aug. 13, 1998) <http://www.fcc.gov/cib/eas/easinfo.txt>.

[57] *Emergency Alert Sys. (EAS) Activation Reports Voluntarily Submitted by Broadcasters to the FCC in 1998*, FCC EAS FAX (Aug. 17, 1998). Because the reporting of activations is voluntary, it is generally assumed that the total number of EAS activations is much higher.

[58] *Report and Order and Further Notice of Proposed Rulemaking* in FO Docket Nos. 91-301 and 91-171, 10 FCC Rcd 1786, 1729 (1994).